Shallow Water Acoustic Experiment Analysis

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LONG-TERM GOALS

The main long-term goals of the research are to quantify (1) the frequency dependence of the sound speed and attenuation in marine sediments from low to mid frequencies, and (2) the coupling of physical mechanisms in the water column and the seabed in complex range- and azimuth-dependent littoral waveguides.

OBJECTIVES

The main objective of the current research is to determine the frequency dependence of the sediment sound speed and attenuation in the 25-3000 Hz band in the Shallow Water 2006 (SW06) experimental region where two Shallow Water Acoustic Measurement (SWAMI) arrays were deployed. An additional objective is to examine ambient noise characteristics in the Philippine Sea in the late 1980s from data recovered on analog tape.

APPROACH

The central hypothesis of the research with regard to SW06 is that the frequency dependence of the sound speed and attenuation in the seabed can be inferred by acoustic measurements in the water column. The measurements require a sufficiently large bandwidth and source-receiver spatial scale with adequate physical measurements in the water column and seabed during the time frame of the acoustic measurements. During August-September 2006 in the SW06 area, extensive narrowband and broadband acoustic measurements in the 10-3000 Hz band were made on two SWAMI L-arrays separated by approximately 20 km. Other acoustic arrays were deployed by Woods Hole Oceanographic Institute and the SCRIPPS Institute of Oceanography. The propagation track connecting the two arrays was on an approximate isobath (~ 70 meters water depth). The specific locations of the L-arrays were chosen on the basis of prior geophysical measurements that indicated a nearly uniform high-speed sandy sediment with a first layer thickness of 5-10 meters.   The approximate locations of SWAMI-32 (a 32-elelment L-array) and SWAMI-52 (a 52-element L-array) were 39° 3.67' N, 73° 7.84' W and 39° 12' N, 72° 57.97' W, respectively. The scientific methodology to infer basic seabed acoustics includes the use of independent acoustic data. For these analyses broadband signals from light bulb implosions and combustive sound sources and CW tow data from 50-3000 Hz were processed within an iterative scheme that includes full-field inversion techniques to extract sound speed and attenuation as a function of frequency in a model-independent manner.

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14. ABSTRACT
The main long-term goals of the research are to quantify (1) the frequency dependence of the sound speed and attenuation in marine sediments from low to mid frequencies, and (2) the coupling of physical mechanisms in the water column and the seabed in complex range- and azimuth-dependent littoral waveguides.

15. SUBJECT TERMS

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With regard to the character of ambient noise in the Philippine Sea data were recovered from analog tape recordings in the late 1980s using a method previously developed with funding from the Office of Naval Research. These recovered data were then analyzed for the information they contained on the frequency and wind dependence of the ambient noise below the critical depth.

David Knobles is the lead researcher on this project. He is being assisted by Joshi Sumedh and Vian Nguyen in computer programming and data reduction. Jack Shooter and Thomas Demary assisted in the analog tape recovery.

WORK COMPLETED

A first-order result using the above mentioned iterative scheme has already been presented at the ASA meeting in Salt Lake City, Utah in June 2007 and was compared to theoretical predictions made by the Biot model. The inferred attenuation values suggest a transition frequency located in the 1.5-2.5 kHz band. Further, ambient noise values have been obtained for two locations in the Philippine Sea and compared to previous results obtained in the NE Pacific.

RESULTS

Geo-acoustic inversion calculations have been made from both broadband and narrowband acoustic data collected on both L-arrays. Figure 1 shows an example of a geo-acoustic inversion result using narrowband complex spectra collected on the SWAMI-52 array[1-2]. Shown are the measured and modeled (post-inversion) transmission loss (TL) along with the cost function envelopes for source track and geo-acoustic parameters. The parameter labeled *Ratio (layer 1)* refers to the sound speed ratio at the first sediment layer. The minimum in the cost function is located at a value of about 1.1 and gives a surface sound speed of about 1650 m/s.
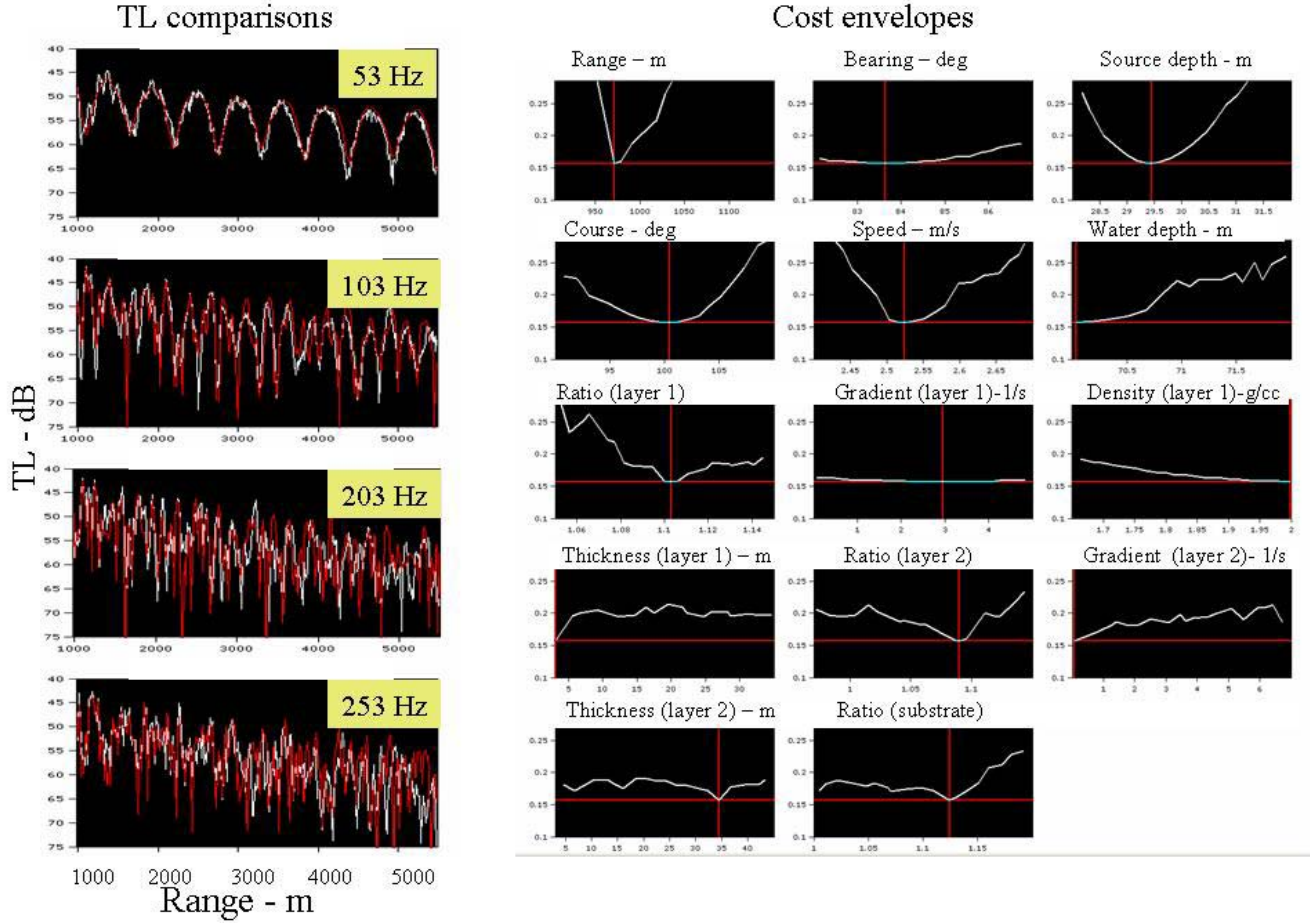
TL comparisons

Cost envelopes

Figure 1: Inversion results (model-data TL comparisons and envelopes of cost distributions) using narrowband acoustic data collected on SWAMI-52.

Figure 2 shows a comparison of measured and modeled time series. The measurements were made on the SWAMI-32 L-array, and the source was a combustive sound source. The modeled time series was produced from a geo-acoustic profile similar to that inferred from the narrowband inversions on the SWAMI-52 L-array. The frequency response (computed with a normal mode model) was convolved with a measured source spectrum to generate a modeled received spectrum. These comparisons, along with the TL comparisons in Figure 1, suggest that the geo-acoustic profile for the seabed in the region of the two SWAMI locations has been approximately determined.
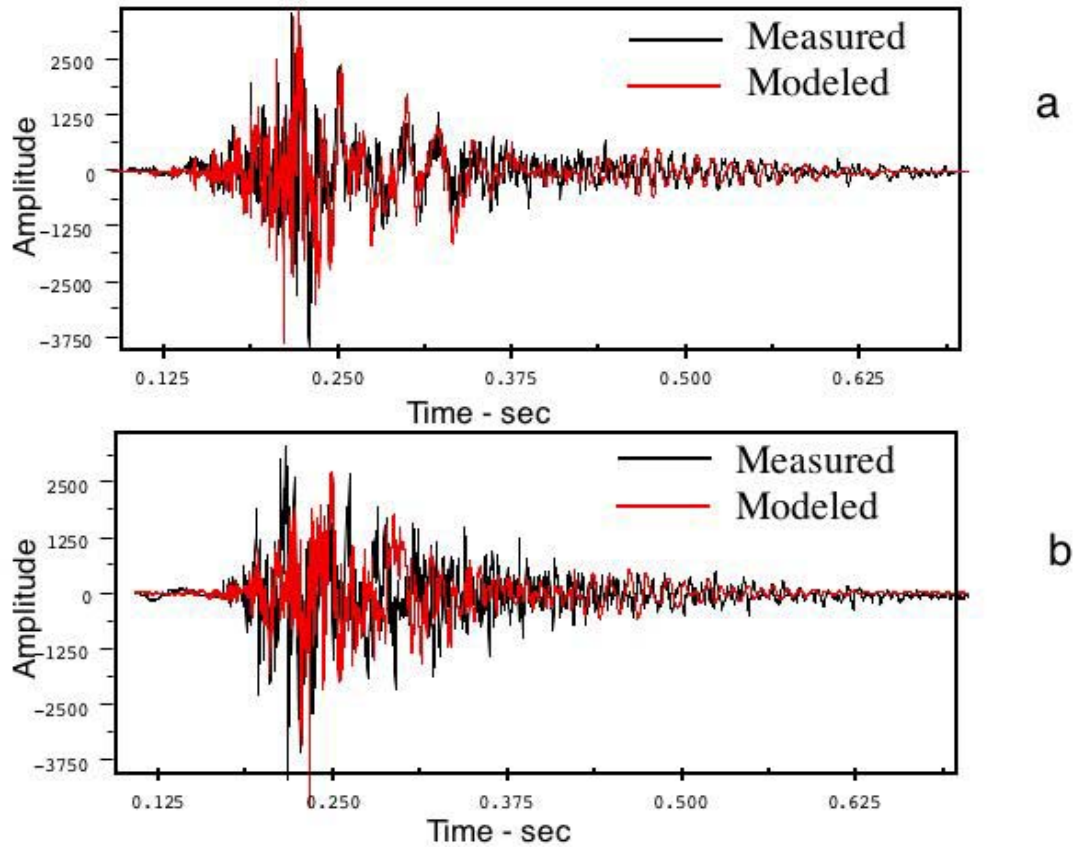
Figure 2: Comparison of model and measured received time series at SWAMI-32 generated by a combustive sound source for ranges of (a) 4.7 km and (b) 3.2 km. Bandwidth is 10-3000 Hz. Amplitude units are arbitrary.
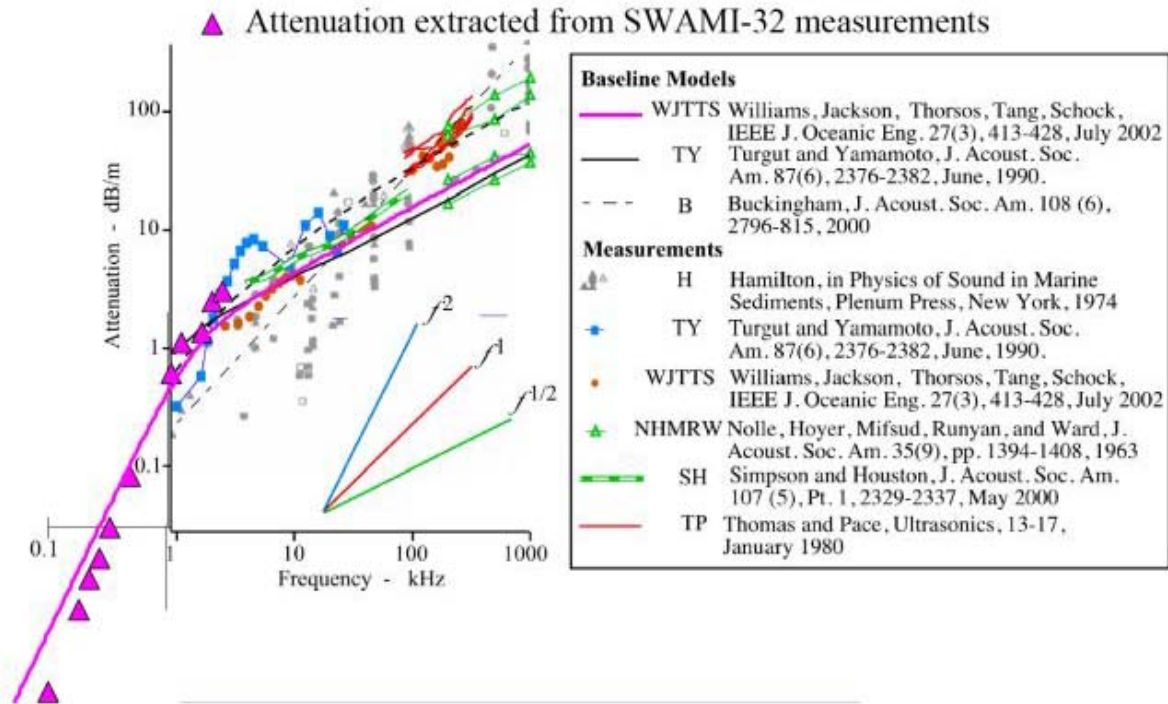
Figure 3: Inferred values of seabed attenuation from the SW06 measurements compared to previously reported values and various model predictions.

Figure 3 shows the inferred values of attenuation (dB/meter) as a function of frequency determined for the first sediment layer. These values are compared to a variety of reported measurements and model predictions. The method for extracting the attenuation values was to use the sound speed and density structure of the seabed, as determined from the inversions, to model TL that was measured over a large source-receiver range scale (out to 20 km) for 53, 103, 203, 253, 303, 403, 503, 1153, 1503, 2004, 2503, and 2953 Hz. The attenuation in the first sediment layer was adjusted to obtain an optimum fit for of the TL versus range for each frequency. The scientific principle used is that once the sound speed structure of the seabed (and the water column) is known approximately, the average TL as a function of range in shallow water is controlled by the intrinsic attenuation. One observes that the inferred attenuation values appear to be consistent with a prediction made by an approximation introduced by Williams et al. to the Biot model.
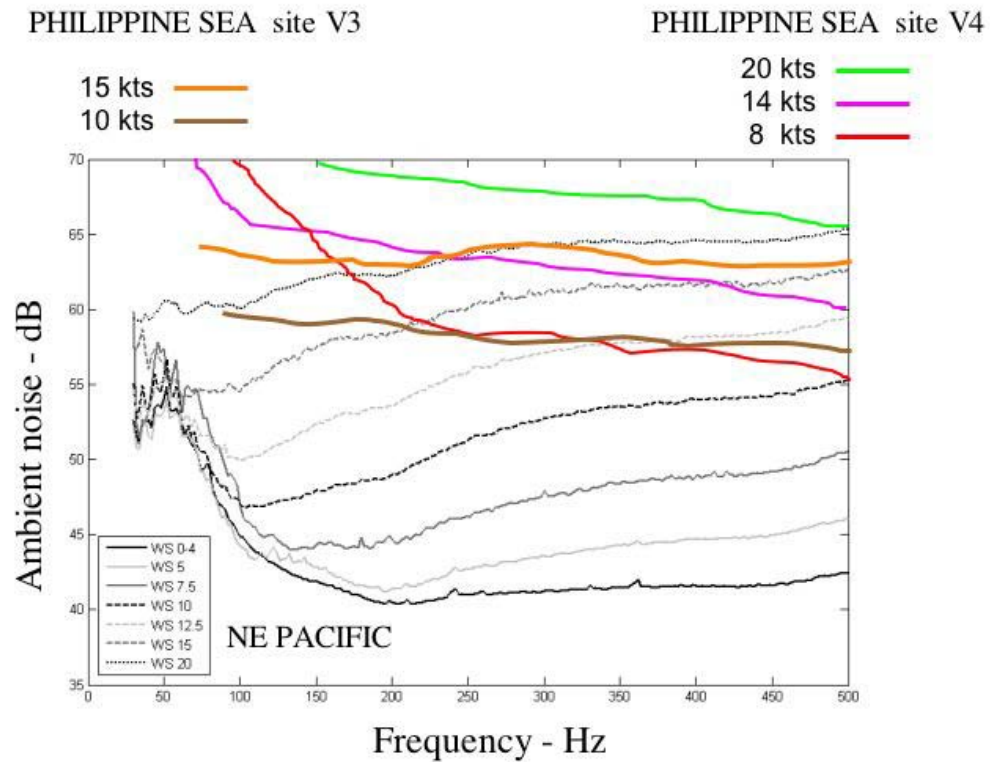
*Figure 4 : Comparison of ambient noise obtained from analysis
of Philippine Sea data to previous results for NW Pacific*

Figure 4 compares ambient noise values inferred from data taken at two locations (V3 and V4) in the Philippine Sea to ambient noise values obtained on a similar measurement system in the NE Pacific[3]. The NE Pacific location had significantly less distant shipping noise as compared to the Philippine Sea locations because of the proximity to shipping lanes (within about 100 miles for the Philippine Sea location as compared to 500 miles for the NE Pacific data). The important observation is that at 500 Hz, where distant shipping has only a small contribution, one observes ambient noise values that appear to be only dependent on wind speed as opposed to location. This is expected in deep water where the main contribution from wind dominated noise arises from propagation within the Reliable Acoustic Path (RAP) range. Within RAP range bottom interaction effects are mitigated because of high bottom loss at large grazing angles. This is not the case in shallow water and it has been previously demonstrated that wind dominated noise as a function of wind speed is highly variable for different locations[4].

IMPACT/APPLICATIONS

One potential impact of this research is an unique experimental determination of the seabed attenuation that can serve as a test for existing and future theoretical models of sound propagation in marine sediments. In addition signal processing techniques developed for the inversion of the acoustic data on the L-arrays may be applicable to detection and localization on passive arrays.

TRANSITIONS

At this time the main transition of this research is applied inversion model development.

RELATED PROJECTS

None.

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